DOCUMENT RESUME

ED 292 663 SE 049 017

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TITLE Assessing the Skill of Variable Identification with Multiple Choice Items.
PUB DATE 88
NOTE 29p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (61st, Lake of the Ozarks, MO, April 10-13, 1988).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Performance Tests; Process Education; Response Style (Tests); Science Education; *Science Tests; *Secondary School Science; *Test Construction; *Test Format; Testing Programs; *Test Items
IDENTIFIERS Process Skills; Science Education Research

ABSTRACT

Increased emphasis on public school accountability has resulted in several states including a science component in their elementary and middle school testing program. This component often includes items designed to measure process skill ability. The purpose of this study was to examine the performance of high school students on four types of multiple choice items used to assess student's ability to identify manipulated and responding variables. Items differed only in the stimulus material presented to students. Stimulus material was either a question focusing on the relationship between two variables, a hypothesis, a description of an experiment, or a description of results of an experiment. Student performance on these item types was compared to their performance on a standard Piagetian interview task of variable identification. The results of the study included: (1) the "question" format was the most difficult, while the "results" format appeared to be the easiest; (2) the "description" item type had a higher correlation with the total interview than any other item type. Among conclusions reached in this study was that although all four item types operate similarly, they did not correlate very highly with the interview/observation task. (CW)

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ASSESSING THE SKILL OF VARIABLE IDENTIFICATION WITH MULTIPLE CHOICE ITEMS

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SE 049 017

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Assessing the Skill of Variable Identification with Multiple Choice Items

Rationale

The increased emphasis on accountability in public education has resulted in numerous states and local testing programs. Several states (e.g. Florida, South Carolina, Texas) have recently included a science component in the assessment of elementary and middle school students. This science component often includes items designed to measure process skill ability. Typically, process skill items are multiple choice format and do not include interaction with materials other than pencil and paper. Tests developed at the state and local level parallel those developed by science educators (e.g. Dillashaw & Okey, 1980; Cronin & Padilla, 1986; McKenzie & Padilla, 1986).

While the tests purport to measure process skill ability, it is interesting to note the form of the stimulus material. For example, in measuring the skill of variable identification the Test of Integrated Process Skills (TIPS, Dillashaw & Okey, 1980) and the Middle Grades Integrated Process Skills Test (MIPT, Cronin & Padilla, 1986) present a description of an experiment and ask the student to identify the manipulated (independent) or responding (dependent) variable. This approximates what may happen in the classroom when a teacher leads students in the planning and conducting of an experiment. However, it may be

argued that students might be successful identifying variables in a "concrete, hands-on" situation and fail to identify variables from the written description of an experiment, a more abstract situation.

Testing strategies employed by classroom teachers or district level personnel to measure process skill ability may take various forms. Teachers may assess their students' level of proficiency by using a checklist during a hands-on experiment or investigation. Another logical methods of assessment would be to use multiple choice items in which an experiment or investigation is described (as in TIPS and MIPT). While both of these methods of assessment may be employed, it is questionnable if they are of equal difficulty for students.

Not only are we assessing process skill ability with both performance based observation and multiple choice items, but there exists a great deal of variability in the way multiple choice items are presented. For example, in a survey of multiple choice items used to measure the skill of variable identification, four different types were identified. Some items included a description of an experiment while others presented a written hypothesis, a science question, or the results of an experiment.

Purpose

The purpose of this study was to examine four types of multiple choice items used to assess students' ability to identify manipulated and responding variables. The items differed only in

the stimulus material presented to the student. Stimulus material was either a question, hypothesis, description of an experiment, or description of the results of an experiment. An example of each of the four item types examined follows:

Question

Sara wanted to find the answer to this question: "How does the number of batteries in a circuit affect the brightness of a bulb in the current?" If she answered this question by doing an experiment, what would be the responding variable?

Hypothesis

Sara conducted an experiment to test this hypothesis: "As the number of batteries in a circuit increases, the brightness of a bulb in the circuit increases." What is the responding variable in this experiment?

Description of an Experiment

Sara constructed a circuit made of one battery and one bulb. She noted the brightness of the bulb. She then added another battery to the circuit and noted the bulb's brightness. She continued this experiment by placing three and then four batteries in the circuit. What is the responding variable in this experiment?

Description of the Results of an Experiment

Sara conducted an experiment and found that as she increased the number of batteries in a circuit the brightness of the bulb in

the circuit increased. What is the responding variable in this experiment?

In each of these four item types the same answer choices would be available to the students. For example:

a. number of bulbs

b. number of batteries

c. bulb brightness

d. battery strength

In addition to examining subject performance across the four item types, performance on these items was compared to the subject's ability to identify manipulated and responding variables during a hands-on investigation. This involved interviewing each student, during two experimental situations, to ascertain their ability to identify manipulated and responding variables. The following research questions provided the focus of this study:

1. Is there a difference in student performance across the four multiple choice items types?

2. Is there a difference in the correlations between student scores on the four multiple choice item types and scores received during the hands-on investigation?

3. Is there a difference in student performance on items designed to measure the ability to identify manipulated variables and responding variables?

Procedure and Data Analysis

A sixteen item multiple choice test designed to measure the skill of variable identification was developed. Four items were written for each of the four item types previously described. Eight items (two per item type) require the subject to identify manipulated variables, while the remaining eight items (two per item type) require the identification of responding variables. Therefore, the total test could be broken into an eight item manipulated variable subtest and an eight item responding variable subtest. The test was then reviewed by a panel of educators. The panel, comprised of science educators, classroom teachers and scientists, provided comments on item appropriateness and clarity. Items were revised as indicated by the panel. A sample item is included as Figure 1.

The variable identification test was administrated to a sample of high school students (n = 54). The sample was drawn from a high school in Southeast Louisiana in which process skills are included in the science curriculum. All subjects had been taught the terms manipulated variable and responding variable and had practiced identifying variables in experimental situations. Twenty five of the students were freshman with the remaining twenty nine sophomores. There were seventeen males in the study

and thirty seven females. Scores for this administration of the tests yielded a reliability estimate of .53 (KR-20).

Each student was also observed and questioned while conducting two investigations. One investigation focused on identification of manipulated variables. Subjects were provided with a pendulum consisting of two different lengths of string and several bobs of different sizes and weights. Each subject was asked to identify variables that might affect the number of swings the pendulum would make in a given amount of time. The other investigation dealt with the identification of responding variables. Subjects were given a seltzer table to dissolve in a container of room temperature water. They were then given containers of warm and cold water and were asked to identify variables that might change or be different if seltzer tablets were dissolved in water of different temperatures. In an attempt to assure reliability of interviewers, a script was used in questioning the students during the investigations. The script used during one of the investigations is included as figure 2. Subjects were scored on their ability to identify variables while conducting each of the two investigations, using the following scheme. If a subject would not identify any variables, a score of 0 was assigned. Subjects identifying one variable were assigned a score of 1, two variables were assigned a score of two, while those identifying more than two variables were assigned a score of 3.

A testing scheme was used to control for the effects of the order on testing. Subjects were randomly assigned to one of four groups identified below:

W M R

W R M

M R W

R M W

W = Written test

M = Manipulated Variable Investigation

R = Responding Variable Identificaiton

Analysis of variance procedures revealed there were no statistically significant differences in the scores on either the written test or the investigations across these four groups. The four groups were collasped into one group for further analysis.

Descriptive statistics and Spearman correlation coefficients were computed for all tests and subtests. Analysis of variance procedures were used to determine if difference existed on student scores across the four item types as well as between the manipulated variable and responding variable subtests.

Results and Conclusions

The following results based on the aforementioned research questions were obtained.

1. Is there a difference in student's performance across the four multiple choice item types?

The subjects scored lowest on those items presented using the "question" format (1.72 out of a possible 4) (see Table 1). Scores were highest on items using the "results" format (2.46 out of a possible 4). There was no statistically significant differences in performance across the four item types.

2. Is there a difference in the correlation between student scores on the four item types and scores received during the hands-on investigation?

The correlations between the four item types and the total investigation score ranged from -.06 to .24 (see Table 2). Furthermore the correlation between scores on the written manipulated and responding variable subtests and the hands-on investigating were also very low (-.09 to .15). This indicates that students might be classified differently on the basis of their ability to identify variables in these two testing situations.

3. Is there a difference in student's performance on items designed to measure their ability to identify manipulated variables and responding variables?

Although the mean scores on the written manipulated and written responding variable subtest were very similar (4.24 and 4.09 respectively out of possible 8), the correlation between these two subtests was negative ($r = -.05$) (see Tables 1 and 2). A positive correlation was noted between the manipulated investigation task and the responding investigation task, however,

this correlation was low (r = .18). The means of the manipulated and responding interview tasks (2.24 and 1.69, respectively, out of a possible 3), were not significantly different.

From this investigation the following conclusions appear tenable:

1. Although all 4 item types operate similarly, they do not correlate highly with the interview/observation task.

2. If a teacher only assesses students through observation, students may have difficulty in doing well on written tests and vice versa. Perhaps we need to assess with both interview/observation and multiple choice items.

3. Since there was a low correlation between manipulated and responding variable tests, perhaps knowing how to identify one does not assure students can identify the other.

The results of this research project indicates that educators may not be accurately assesing process skill ability. This may be especially relevant when identification of manipulated and responding variables are involved. Since there was a low correlation between the manipulated and responding variable tests and no significant difference between item types, then science educators should possibly use more than one type of evaluation when testing students on variable identification. With tremendous emphasis placed upon standardized test scores, science educators

must tenor the results with the idea that a paper and pencil test may not be the best way to evaluate application level knowledge.

References

Cronin, L. L., & Padilla, M. J. (1986, March). The development of a middle grades integrated science process skills test. Paper presented at the meeting of the National Association for Research in Science Teaching, San Francisco, CA.

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McKenzie, D. L., & Padilla, M. J. (1986). The construction and validation of the Test of Graphing in Science (TOGS). Journal of Research in Science Teaching, 23, 571-579.

A physical education teacher conducted an experiment with her class. She found that the students' pulse rate was higher when they were active than when resting.

What is the responding variable in this experiment?

A. Amount of activity

B. Type of activity

C. Students' pulse rate

D. Students' weight

Figure 1. Sample item from the variable identification test

RESPONDING VARIABLES
SELTZER TABLET

E	"Here is a glass of water that is at room temperature."
S	Given time to feel the glass and/or water.
E	"I am going to drop a seltzer tablet in this glass of water. I want you to watch what happens when I drop the seltzer tablet into the water."
S	Allowed to watch the dissolving tablet.
E	"Here is a glass of hot water and a glass of cold water."
S	Given time to feel the glass and/or water.
E	"We just dropped a seltzer tablet into the water that is at room temperature. Now if we conduct an experiment and drop a seltzer tablet into the glass of hot water what things might be different from when the seltzer tablet was dropped into the glass of water that is at room temperature? What would be some responding variables?
S	Given time to respond.
E.	If only one variable is given ask "Are there any more responding variables you can think of?"
E.	"If we now drop a seltzer table in the glass of cold water what thing might be different? What would be some responding variables?
S	Given time to respond.
E	If only one variable is given ask "Are there any more responding variables you can think of?
END	

Figure 2. Script for Responding Variable Investigations

Table I

Mean Scores and Standard Deviations
Post Measures

Measure	N	Maximum Score	$\bar{X}$	SD	Range
Total Variable Identification Test	54	16	8.33	2.78	3-15
Manipulated Subtest	54	8	4.24	1.64	1-7
Responding Subtest	54	8	4.09	2.27	0-8
Question Format	54	4	1.72	.94	0-3
Results Format	54	4	2.46	1.04	0-4
Hypothesis Format	54	4	2.15	1.04	0-4
Description Format	54	4	2.02	1.00	0-4
Total Investigation Score	54	6	3.93	1.13	2-6
Manipulated Investigation Score	54	3	2.24	.73	
Responding Investigation Score	54	3	1.69	.75	1-3

Table 2

Chart of Correlation Coefficients for All Measures

	T	M	R	Q	R	H	D	TI	MI	RI
T										
M	.47*									
R	.82*	-.05								
Q	.68*	.41*	.53*							
R	.60*	.23*	.59*	.04						
H	.66*	.34*	.60	.45*	.31*					
D	.67*	.43*	.47*	.37*	.35*	.13				
TI	.03	.06	.01	-.01	-.02	-.06	.24*			
MI	.06	-.09	.09	-.00	.01	-.06	.18	.73*		
RV	.00	.15	-.06	-.00	-.04	-.05	.20	.71*	.18	

T = Total Variable Identification Test
M = Manipulated Subtest
R = Responding Subtest
Q = Question Format
R = Results Format
H = Hypothesis Format
D = Description Format
TI = Total Investigation
MI = Manipulated Investigation
RI = Responding Investigation

*significant at .05 level